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ABSTRACT

Two computer assisted instruction programs tested the effects of plain and enhanced screen designs with or without information about those designs and task-type on time and learning. Subjects were 140 fourth grade students in Lincoln, Nebraska who had extensive prior experience with computers. The enhanced versions used headings, directive cues, running heads, and graphic devices to organize and structure the content. One program required learners to perform a memorization task, while the second involved concept acquisition and concept application. The information provided with one version of the memorization lesson described the purpose of the enhanced features and instructed the students to use those features while studying. Although the plain screen versions were found to be equal to the enhanced versions in learning, descriptions of text enhancements reduced lesson time when one of the enhancements provided the learner with program control options. The text is supplemented by 5 figures, 7 tables, and 25 references. (EW)

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The Effect of CRT Screen Design on Learning

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Abstract

Two CAI programs tested the effect of plain and enhanced screen designs with or without information about those designs and task-type on time and learning. The enhanced versions used headings, directive cues, running heads, and graphic devices to organize and structure the content. One program required learners to perform a memorization task, the second required concept acquisition and concept application. The information described the purposes of the enhanced features and instructed the students to use those features while studying. The plain-screen versions were equal to the enhanced versions in learning. Descriptions of text enhancements reduced lesson time when one of the enhancements provided the learner with program control options.

Introduction

Problem Description

The display of instructional text is not solely a function of the author's writing, but also of the publisher's layout design and selected medium, whether that medium is paper or electronic text. In both types of media, text format elements (see Table 1) are combined to create "pages" and "screens" of information. In the case of print media, pages are usually arbitrary points for dividing text, whereas in electronic text, screens serve as logical units of information. The representation of an author's instructional message in the selected medium, though, is not where the problem of design ends, for instructional text has an additional function. Instructional text must encourage an interaction between learner and text; it must facilitate the cognitive processes of reading and leearning. The primary design problem, then, is to identify those combinations of text elements which facilitate specific learning processes.

Manipulations of text elements fall into two general categories: efforts to imitate the effective stimulus and efforts to facilitate the reading and learning cycles with mathemagenic devices or activities (for reviews of this research see Grabinger, 1984; Hartley, 1982, 1985, 1987). Phrase chunking, which focused on making the printed page, or nominal stimulus, mirror the readers' perceived image of the printed page, or effective stimulus, usually had little effect on reading speed or comprehen-

sion (Carver, 1978; Pynte and Noizet, 1980). This lack of effect may be due to the undefined and dynamic nature of the effective stimulus, for it is difficult to imitate something that cannot be seen, something that is in a constant state of change, and something that varies from individual to individual. On the other hand, efforts aimed at facilitating the interactive processes of reading and learning through the use of headings, questions, hierarchical paragraph indentation, and directive cues sometimes improved comprehension when those activities were directly related to specific objectives and when the reader was aware of their purposes (Bausell and Jenkins, 1977; Frase and Schwartz, 1979; Hartley, Bartlett, and Branthwaite, 1980; Hartley and Trueman, 1982.)

The main conclusions drawn from these findings suggest that successful design strategies are those that reinforce and facilitate the reading and perceptual cycles. Though generalizations can be reached about the effective uses of some specific elements in defined circumstances, it is difficult to draw conclusions about combinations of the vast majority of less intrusive text elements—elements that do not overtly direct specific cognitive processes.

Discovering the effect of combinations of elements is made difficult by the large number of text elements in operation at one time. To simplify the research problem, a way to categorize those variables was developed (Grabinger, 1984, 1987; Grabinger and Amedeo, 1987). This classification scheme is based on viewers' judgments about screens. Viewers who evaluated model screens composed of a variety of text elements preferred designs that appear organized, structured, and/or simple. Organization refers to designs that have clear-cut segments of text using indentation or graphic organizers such as boxes, windows, or areas of shading or color. Structure is a more refined level of organized text, referring to text designs that indicate a hierarchical and systematic arrangement of subject material utilizing running heads, headings, increased space between paragraphs and, directive cues. Simplicity refers to short, concise, and spacious looking screens.

In other words, it was discovered that the design of the page or screen suggests something about the content of the text on the page. Individual text elements contribute to a "whole" screen or page image and, while individual elements are perceived, it is the overall combination that affects the viewer. The viewer, as a result of that overall combination, makes judgments about the content of the text. The question raised, then, is whether the graphic arrangement of the information does more than suggest something about the content of the text such as, does the arrangement effect how the learner approaches the text, and in turn, learning from the text? An answer to that question may lead to the development of guidelines for designers of electronic text generally and of CAI specifically, guidelines that may point to relationships between text design features and the activation of cognitive processes and learning strategies.

In an effort to answer that question, the aforementioned constructs of structure, organization, and simplicity were used to guide the design of screens in several versions of two CAI programs. Two types of screens were used: plain and enhanced. Plain screens suggested little about the content of the text while the enhanced screens presented structured and organized displays.

In addition to the screen layout two other variables were included in the text design. First, to vary the types of outcomes expected from the learners, two types of tasks, memorization and concept learning, were included in the program designs. It is also recommended that readers be informed of special textual design devices and how to use them (Pace, 1985), so descriptions about the screen designs were included in some of the program versions.

It was predicted that students who used the enhanced screen versions would invest more mental effort in studying the material. Therefore, students using the enhanced version would spend more time with the program and, as a result, score higher on both immediate and delayed retention tests than students using the plain versions.

Method

Subjects

Subjects were 140 fourth grade students from three public schools in Lincoln, Nebraska. The students were predominantly white, lower and middle class with 71 females and 69 males. All students were reading at least on the fourth grade level and had had extensive prior experience with computers in the forms of CAI, Logo, and keyboard operation lessons. Participation was voluntary and dependent upon parental permission.

Program Content

Two programs, **Order** and **Orbit**, were produced in several versions utilizing the **Saber** (1985) authoring system, an MS-DOS based program. Within each program, the content, questions, and learning activities were identical. The versions differed in the design of the screens (see Figure 1) and whether any preliminary information and instructions were provided.

Order required a memorization task and taught the spelling of and the order of the planets from the sun. The lesson material was divided into five parts: 1) a brief introduction describing the purpose of the lesson and, in one of the enhanced versions, a description of the purposes of the text elements on the screen; 2) a pretest to test the ability of the students to spell the planet names correctly; 3) a brief section to drill students in the correct spellings of the planets, if spelling deficiencies were found; 4) a section for learning a mnemonic to help memorize the order of the planets from the sun; and 5) a test on the students' ability to list the planets in the proper order.

Orbit taught the concepts of ellipse and planetary orbit and had four versions. The lesson material was divided into four parts: 1) a brief introduction describing the purpose of the lesson and, in the enhanced versions, the purpose of some of the text elements on the screen; 2) the concept of ellipse was explained using examples, nonexamples, and attribute isolation with text, graphics and, animation; 3) students were tested on their ability to identify ellipses from among other shapes; 4) the concept of ellipse was then used to describe the orbits of the planets and to explain how Neptune, at times, becomes the furthest planet from the sun; and 5) a test of their ability to apply the concepts to the Neptune/Pluto phenomenon completed the program.

The Design of the Screens

Overall Standards. All screens (see Figure 1 for models) were designed to meet "recommended legibility" standards. (Recommended standards are not hard and fast rules, but flexible and derived from research in both printed text and electronic text. The most recent and concise summary is in Hartley, 1987.) Lines of text were double spaced, unjustified, and kept to a maximum width of 40 characters. Indentation was used to reflect subordinating ideas. Responses were always made toward the bottom of the screen. One idea was used per screen.

Plain Versions. The plain versions included text, white on black, without headings, directive cues, graphic organizers, or running heads.

Enhanced Versions. Enhanced screens were designed to appear structured and organized, yet spacious and simple. Each screen in the enhanced versions included at least one heading describing the content of the page, a running head at the top of the page to describe the general content and task required in the section of the program the student was in, and at least one directive cue in the form of color highlighting to emphasize an important word or phrase. Where pertinent, a graphic organizer in the form of a box (see Figure 1) or background color change was used to help organize subtopics. A second running head was added to the bottom of the screen in the **Orbit** versions to summarize the keystroke commands to move back and forth among the screens (this second feature is not seen in examples in Figure 1).

The Information. In **Order 3** the information described the text elements of running head, heading, directive cues, and graphic organizers and explained why they were used. The instructions in the **Orbit 2** and **Orbit 4** described the text elements and informed the students how to use special keys to move back and forth between the screens to review material.

Lesson Versions

Order had three versions (see Figure 2). **Order 1,** was a plain. **Order 2** and **Order 3** were enhanced with the additions of a running head, color, boxes, and lines to make the screens appear more organized and structured. Finally, instructions on the meaning of the various text elements and how to use them to study were included with the third version, **Order 3**.

Orbit had four versions. **Orbit 1** was plain. **Orbit 2** was also plain, but included instructions on how to use specific command keys to review previous screens. The screens in **Orbit 3** were enhanced with the additional text elements. **Orbit 4** included the enhanced screens and added the information about the features of the screen and how to return to previous screens for review.

Orbit had four versions because it included the addition of command key descriptions. **Order** had only three versions because a sophisticated branching design controlled student moves to reviews and practice.

Measurements

Three measurements were used as dependent variables: average time-per-screen, immediate recall tests, and delayed retention tests. The total time spent on the program was divided by the total number of screens seen by the student for the time-per-screen (TimPerScr) variable. TimPerScr was used as an indication of whether the added text elements encouraged the student to

spend more time studying, organizing, reflecting, or memorizing the subject material. The tests for the **Order** program were composed of 9 questions requiring the subjects to recall and list the nine planets in order from the sun. The **Orbit** tests were composed of five multiple choice questions asking the subjects to select ellipses from nonexamples and to test their understanding of the Neptune/Pluto phenomenon.

Procedures

Permission to use the public school students limited the time available to an average of 20 minutes per student. The programs were assigned to students in an ordered manner to insure a balance of subjects for each version. Students were assigned to the treatment by the cooperating teachers on a random basis. Students entered the treatment room and sat before an IBM PC with a color monitor. The program was then started. The experimenter pointed out the "ENTER" key, explained its purpose, and monitored the progress of the student. The only assistance offered by the experimenter was to help the student recall the proper key sequence to proceed in the desired manner. No assistance was provided with answering questions asked within the programs. Following completion of the program the students were given a certificate of achievement for participating in the experiment. The delayed retention test (RetTest) was given two weeks later.

Results

Design and Analysis

Since the learning tasks in each program were different, each was analyzed separately. The analysis began with a MANOVA (SPSSx, 1985) to examine the effects of the independent variables of program version, school, and gender with all three dependent variables: TimPerScr, ImTest, and RetTest (see Figure 2). This was followed by a repeated measures ANOVA (BMDP, 1985) of each program version with the dependent variables of ImTest and RetTest. Finally, when necessary, separate one-way ANOVAs were performed to help interpret the repeated measures ANOVA. A predetermined significance level of $p < .05$ was used.

Order

Seventy-eight students from three schools, A, L, and M, used the three **Order** versions. The MANOVA indicated a main effect among schools (Table 2). The follow-up univariate F-test indicated that School L spent significantly more time-per-screen than either schools M or A (Table 3 and Figure 3). The MANOVA reported no differences between gender or among the program versions. The repeated measures analysis showed no difference for main effects between the ImTest and RetTest variables and the program versions, but did indicate an interaction (see Table 4). A one-way ANOVA follow-up (see Table 5 and Figure 4) indicated that students who used **Order 3** (enhanced screens with instructions) scored significantly higher on the delayed retention test (RetTest) than on the immediate computer test (ImTest).

Reliability analyses of the 9-item ImTest and RetTest reported Cronbach Alphas of .83 and .89, respectively.

Orbit

Sixty-two students from two schools, M and A, used the **Orbit** versions. The MANOVA results reported no main effect between the

schools, however there was a significant difference among the program versions (see Table 6) in the TimPerScr variable. The univariate F-test follow-up indicated that students using **Orbit 3** (enhanced screens) spent more time-per-screen than students using the other three versions (see Table 7 and Figure 5). There were no differences between gender or among the program versions within the learning variables (ImTest and RetTest).

Reliability analyses of the 5-item ImTest and RetTest reported Cronbach Alphas of .28 and .53, respectively.

Discussion

Though it was predicted that students would spend more time with the programs with enhanced screens, this difference occurred only in two situations. In one case, students using **Orbit 3** spent significantly more time-per-screen than students using the other **Orbit** versions. (**Orbit 3** included a second running head with key command summaries, but did not include information about the text elements.) If the additional time-per-screen was due to the text element design it would be reasonable to expect users of **Orbit 4** (identical to **Orbit 3** with the addition of the text element descriptions) to have spent a similar amount of time-per-screen; however, the users of **Orbit 4** spent the same amount of time as the users of the other **Orbit** versions. It is more likely, then, that the difference is explained by the lack of instructions and text element descriptions in **Orbit 3**. The students using **Orbit 3** were observed to have experimented with the commands at the bottom of the screen to discover the purposes of the commands. Students using **Orbit 4**, on the other hand, needed no time to experiment because the purpose of each command was explained at the beginning of the program. This would be consistent with Hartley's (1987) recommendations that special design features should be explained to readers in advance.

In the second case, students using the **Order** program in school L spent more time-per-screen than students in schools A and M. No differences among the schools were expected since all of the students were reading on at least the fourth grade level. Although no ability-level data was gathered, subsequent conversations with teachers indicated that there may have been ability differences among the schools.

It was also predicted, on the basis of viewer preferences and classifications, that structured screen designs would provide powerful cues to facilitate mental involvement and thus increase learning from the CAI material. However, the lack of instructional effects attributable solely to the arrangement of text elements indicates that graphic changes alone are not enough to increase mental involvement with the text. There are several explanations which may clarify why a learning effect was not found.

First, interventions that directly involve the learner have been more successful in affecting learning. In a study comparing a mathemagenic activity with a text element change, questions were found superior to highlights in aiding the learning of factual items and in aiding performance on higher cognitive operations (Schloss, Sindelar, and Cartwright, 1986). Additional successful interventions (Davey and Kapinus, 1985; Glynn, Britton, and Muth, 1985; Reder, Charney, and Morgan, 1986; Rieber and Hannafin, 1987; Smith

and Friend, 1986) have involved elaborative, orienting, or generative activities within the structure of the text, though it is not known whether any special changes were implemented on the design of the instructional materials. These changes are also more mathemagenic than design changes to the page.

A second explanation for the lack of learning effect may lie within the individual differences of the students. It was not possible, under the restrictions governing the participation of the schools, to gather more individual data about the students so, the effects of ability was not examined. In addition, all subjects were between 10 and 11 years old. This may be too young for students to recognize specific text elements and then develop strategies to use those elements, for the development of effective learning strategies is in part related to maturation and experience.

A third reason may be found in the instructional design of the software. The instructional design of both programs proved effective, for there were no differences in ImTest or RetTest scores among the versions of each program. **Order** included a mnemonic in its design, which is a powerful learning strategy (Carlson, Kincaid, and Hodgson, 1976). **Orbit** was a highly visual program with some animation, which probably played to a learning strength of young people (Pavio, 1979).

Finally, the screens for all versions, even the plain versions, were designed to be consistent with publication standards. There was no "ringer" version, a version designed so poorly that students would have had difficulty reading it. One of the possible generalizations, then, is that a simple, legible, clean design is as effective as the more complex and structured designs.

There was one result difficult to explain. There appears to be no apparent reason why **Order 3** would score significantly higher on the RetTest than the ImTest. Since this occurred with only one of seven groups, the difference may be the result of a small cell (24) or unknown intervening variables.

Despite the lack of instructional difference, there are implications for both screen design and future research. First, it appears that, for this age group, simple, spacious screens are as effective as more organized and structured designs. It does not appear that fourth graders infer anything about the content from the arrangement of the text elements on the screen, though the effects of enhanced designs on older age groups still needs to be examined. Second, the addition of unexplained text elements to the screen may prove distracting. Although the addition of a command key summary without a description of its purpose did not interfere with learning in this case, its have a negative affect on efficiency. The effect on undescribed text elements may vary with more complex material and different age groups.

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Table 1

Examples of Text Format Elements

line length	type size
type style	leading
heading location	use of directive cues
type of directive cue	number of columns
ink color	paper color
paragraph indication	use of graphic devices
running head location	use of headings
justification	word spacing
character attributes:*	functional areas:**
reverse video	running heads
underlining	directions
italics	student responses
line breaks	error messages
page numbering	feedback to students

(*Isaacs, 1987; **Heines, 1984)

Table 2

MANOVA Results of Differences Among Schools for **Order**

Test	Value	Approx. F	Hypoth. DF	Error DF	Sig.
Pillais	.29611	3.18611	7340.19690	110.0	.006

Table 3

Univariate F-test: Differences Among Schools for **Order**

Variable	SS	Error SS	Hypoth. MS	Error MS	F	Sig.
TimPerScr	.06757	.36264	.03378	.00648	5.21704	.008
ImTest	37.72113	373.81905	18.86056	6.67534	2.82541	.068
RetTest	36.28461	451.70079	18.14231	8.06609	2.24921	.115

Table 4

Repeated Measures ANOVA for **Order** Program

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Tail Prob.
Mean	7340.19690	1	7340.19690	750.18	.0000
Order	2.86386	2	1.43193	.15	.8641
Error	694.70370	71	9.78456		
Main Effect	3.82017	1	3.82017	.83	.3654
2-Way Inter.	32.42773	2	16.21387	3.52	.0348 *
Error	326.86957	71	4.60380		

Table 5

Follow-up ANOVA of Interaction Identified in **Order** Program

Source	Sum of Squares	Degrees of Freedom	Mean Square	F	Tail Prob.	
Mean	2523.00000	1	2523.00000	300.67	.0000	
Error	193.00000	23	8.39130	.15	.8641	
Main Effect	21.33333	1	21.33333	5.94	.0230	*
Error	82.66667	23	3.59420			

Table 6

MANOVA Results of Differences Among **Orbit** Versions

Test	Value	Approx. F	Hypoth. DF	Error DF	Sig.
Pillais	.57965	3.51250	9.00	132.00	.001

Table 7

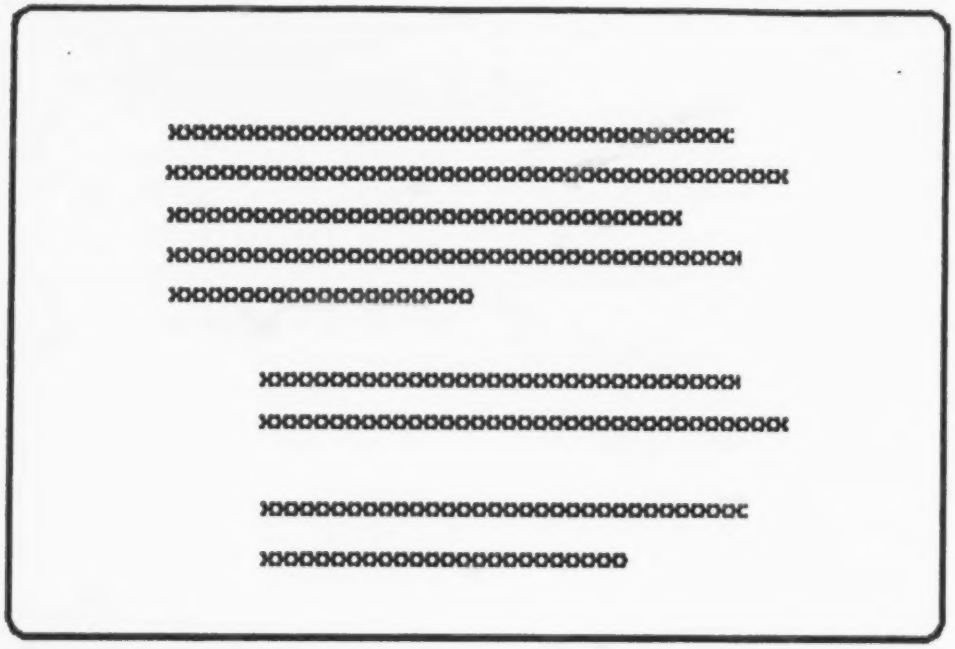
Univariate F-Test: Differences Among **Orbit** Versions

Variable	Hypoth. SS	Error SS	Hypoth. MS	Error MS	F	Sig.
TimPerScr	.29900	.36767	.09967	.00836	11.92746	.000
ImTest	3.91677	92.38214	1.30559	2.09959	.62183	.605
RetTest	4.27161	29.64762	1.42387	.67381	2.11316	.112

Figure 1

Examples of Screens from the CAI Programs

1a. "Plain Vanilla" Screen



1b. Enhanced Screen

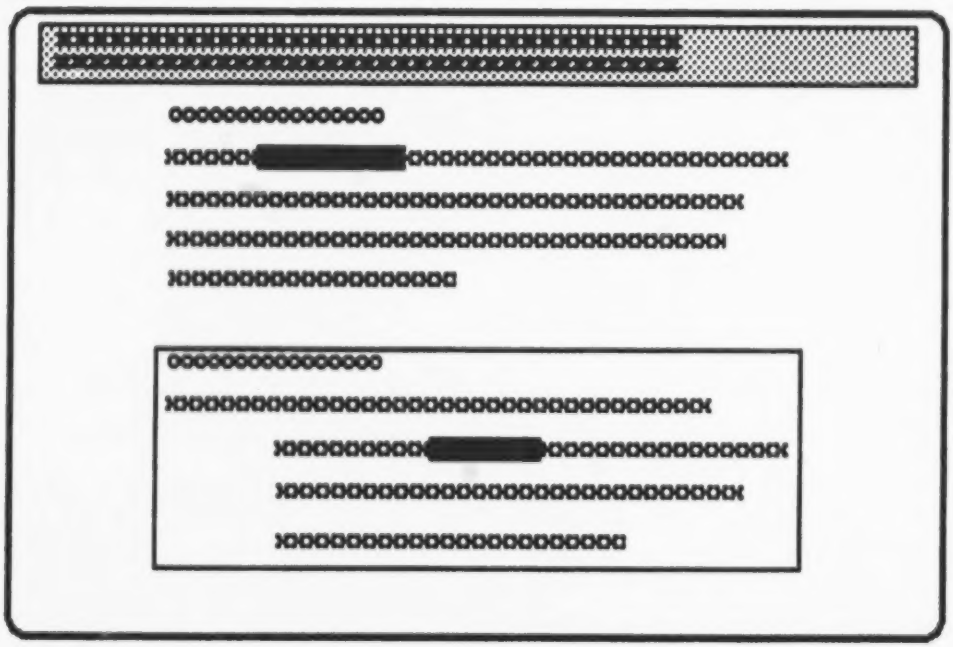


Figure 2

Diagram of Research Analysis

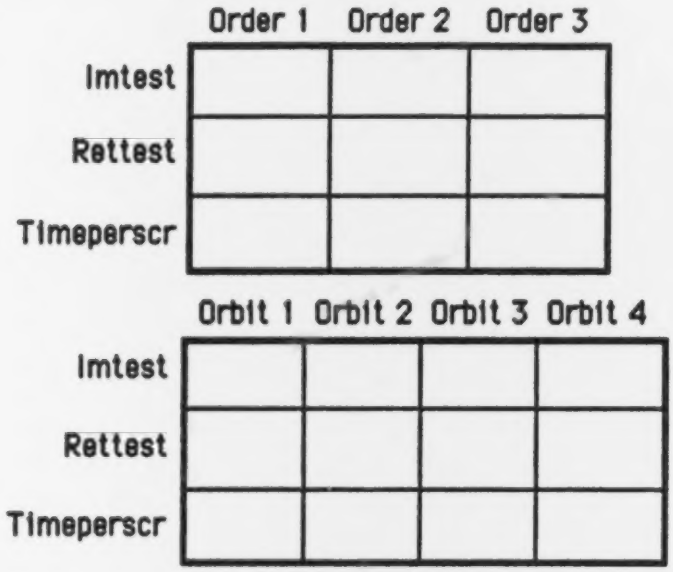


Figure 3

Observed Means Among Schools For TimPerScr

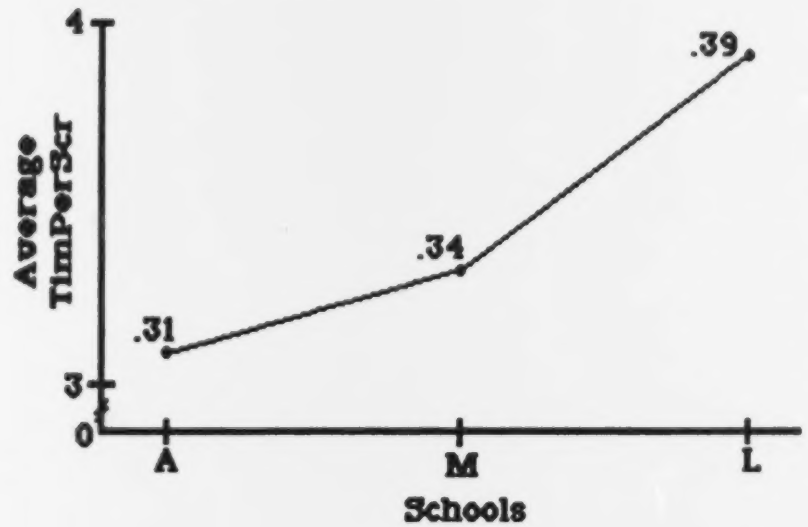


Figure 4

Interaction Program Version and Time of Test for **Order**

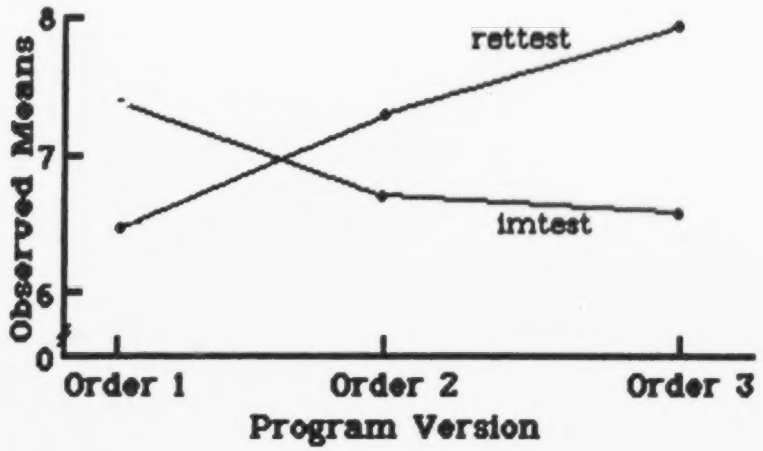


Figure 5

Observed Means for **Orbit** Versions